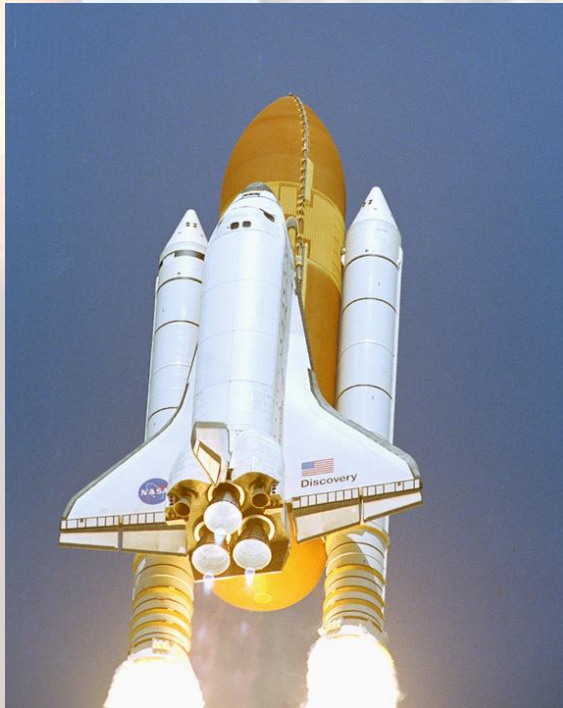


# Design for Operations Space Shuttle vs. Sea Launch

Bo Bejmuk



# Shuttle



**Space Shuttle designed for ascent performance, multi functionality and minimum development cost**

**Result:**

**Costly ground operations  
Costly mission planning  
Costly flight operations**

# Sea Launch



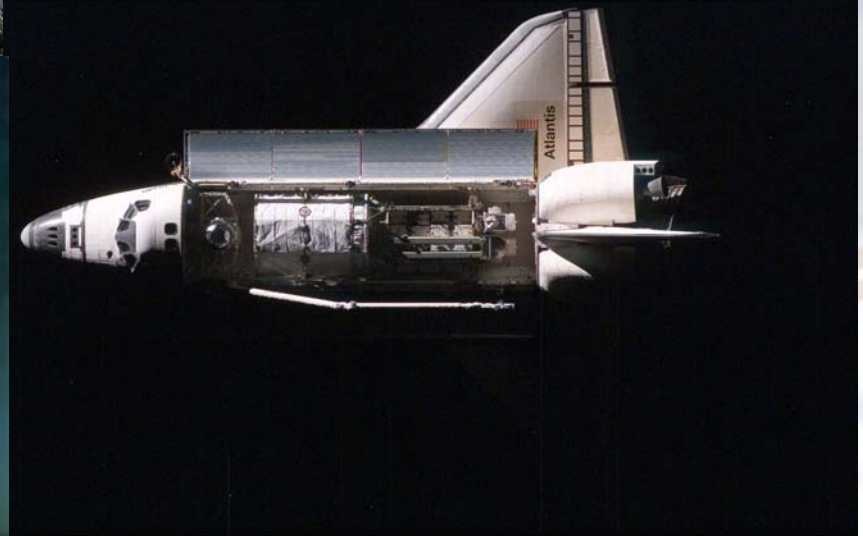
Courtesy of the Sea Launch Company

**Zenit Rocket designed to strict operational requirements**

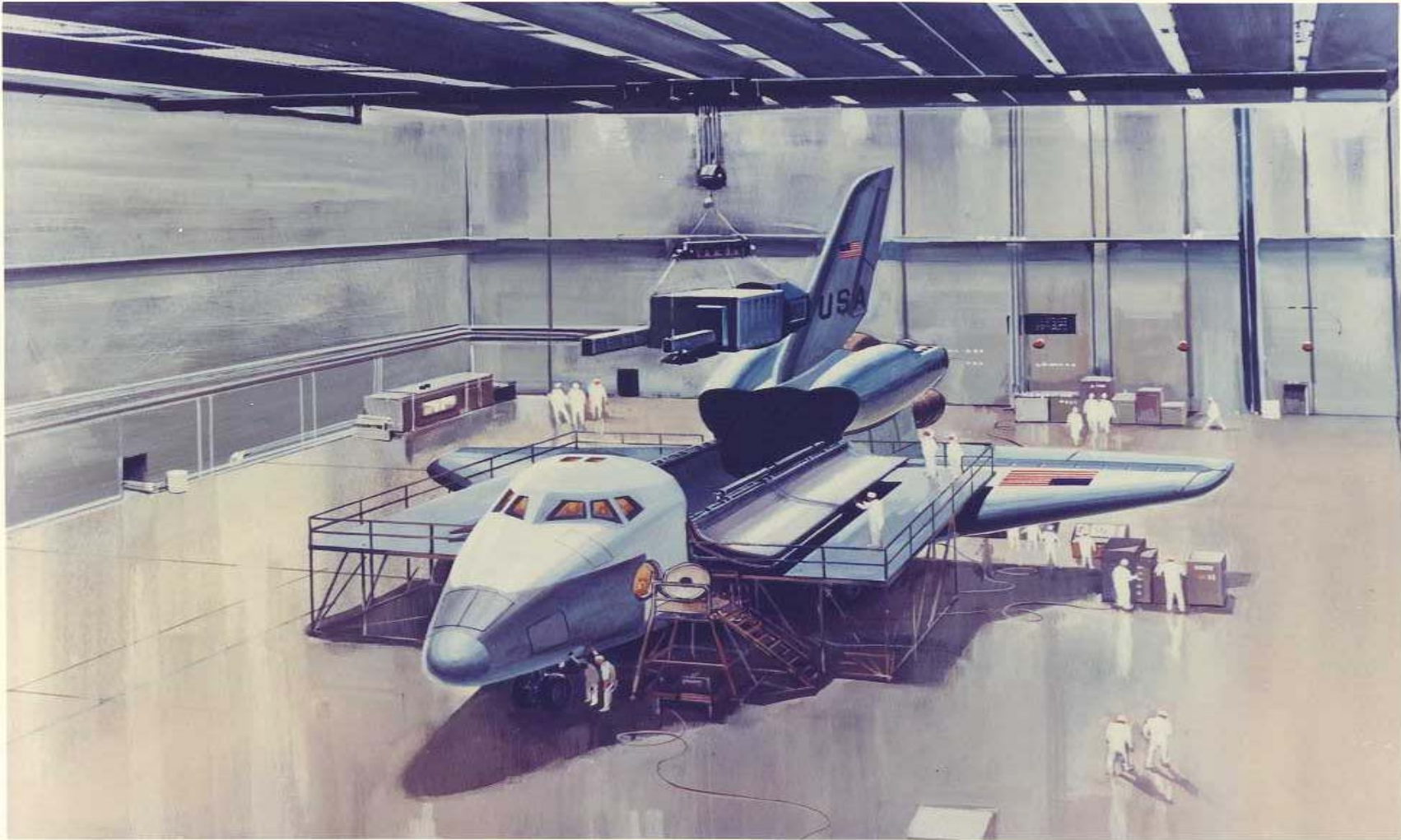
**Result:**

**Automation and robust design  
Simple and cost effective operations  
Great benefit to cost of ownership<sub>2</sub>**

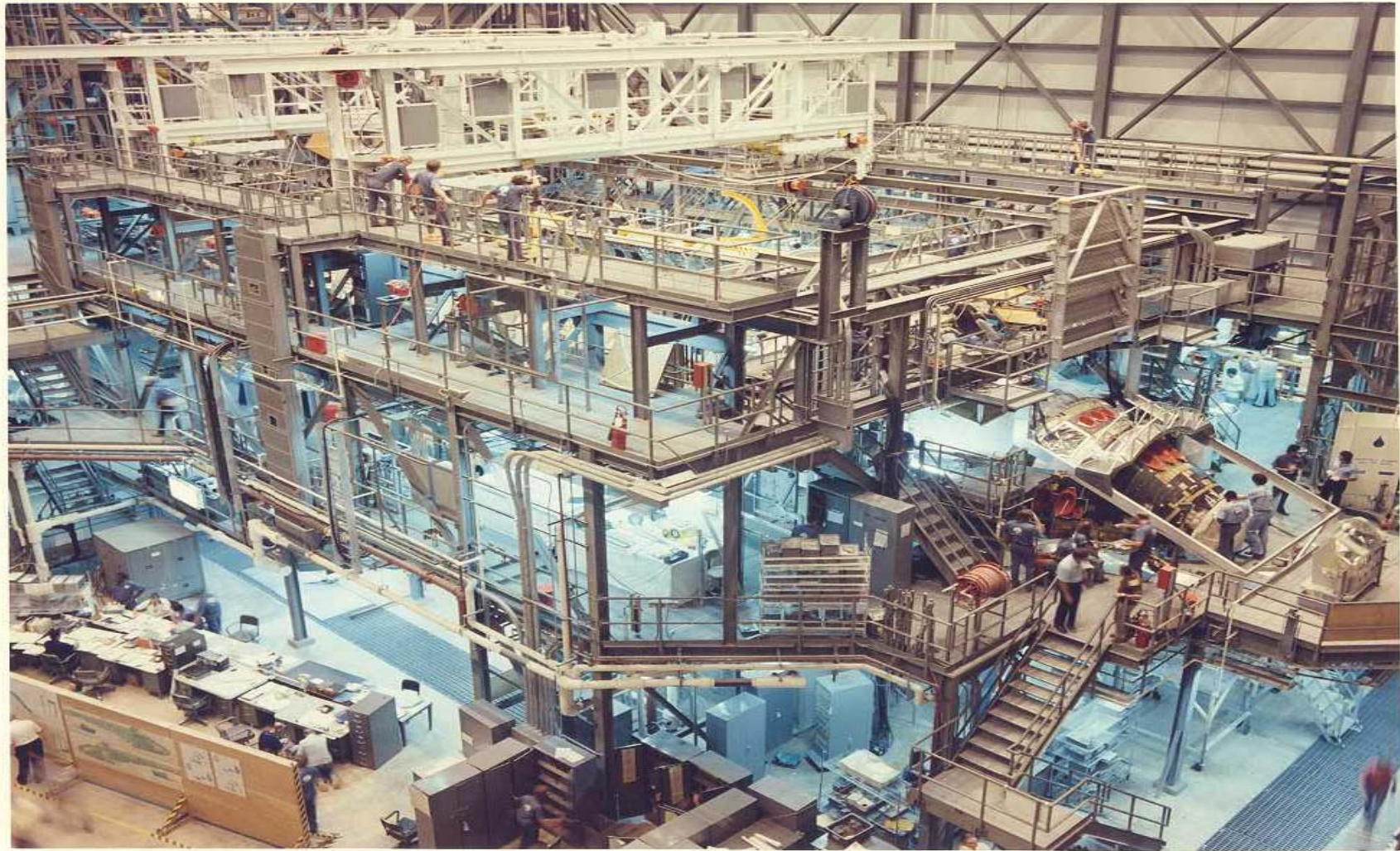
# Space Shuttle – Magnificent flying system but difficult and costly to operate



# Initial Naive Concept of Ground Operations



# Operational Reality



NASA, KSC Photo, dated September 25, 1979, index number "KSC-79PC-500"

# **Lack of Robustness and Design Margins Complicated flight Planning and Increased Cost**

## **Problem**

- The launch probability predictions for early Shuttle flights was less than 50%
  - More than half of the measured winds aloft violated the vehicle's certified boundaries

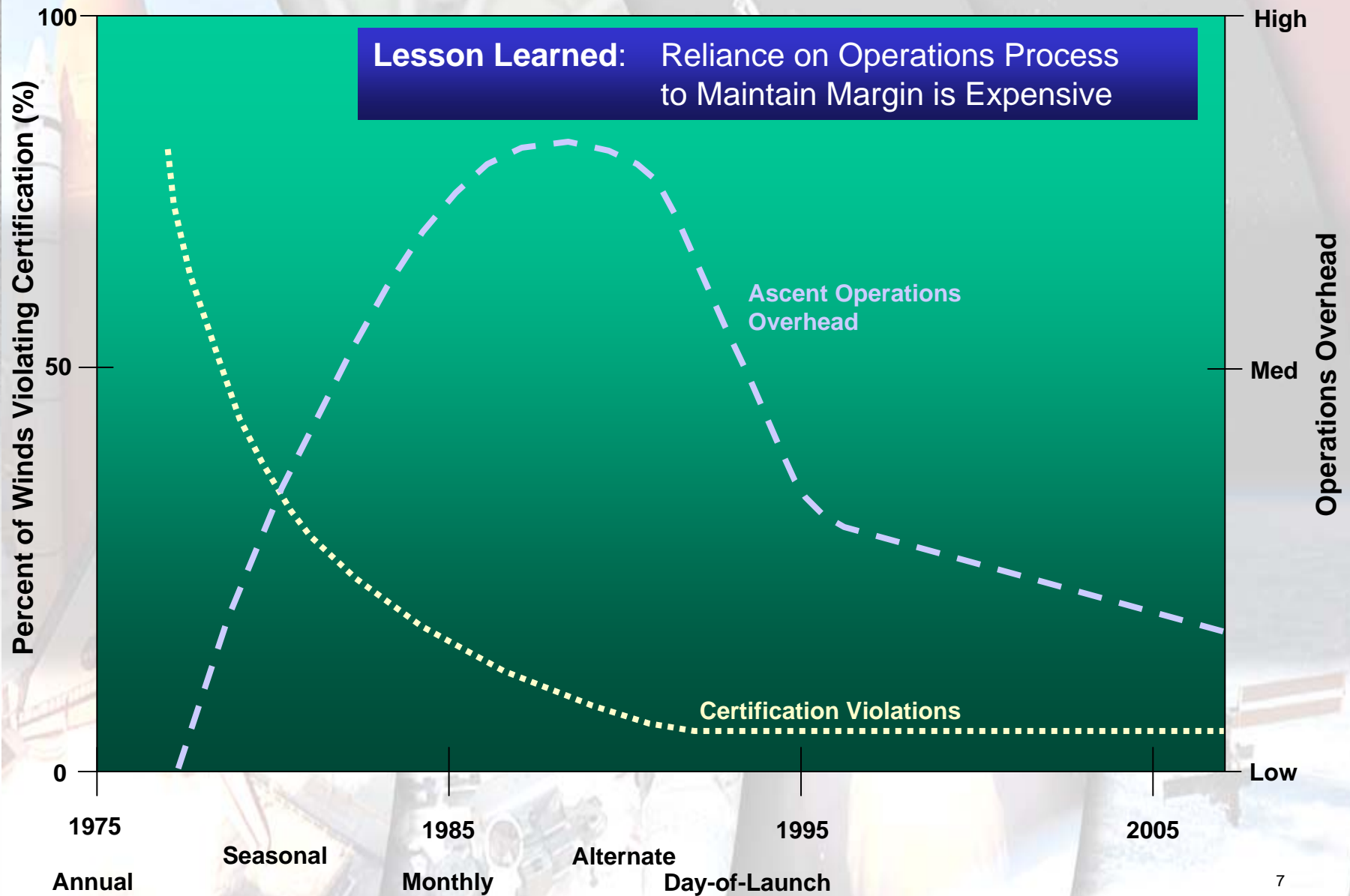
## **Corrective Actions**

- System Integration led the evolution from a single ascent I-load, through seasonal I-loads, alternate I-loads, and finally arriving at DOLILU
- This process extended over a 10+ year period
- Concurrently the Program executed 3 load cycles (Integrated Vehicle Baseline Characterization - IVBC) combined with hardware modifications to expand vehicle certified envelopes
- Current launch probability is well in excess of 95%

## **Lesson**

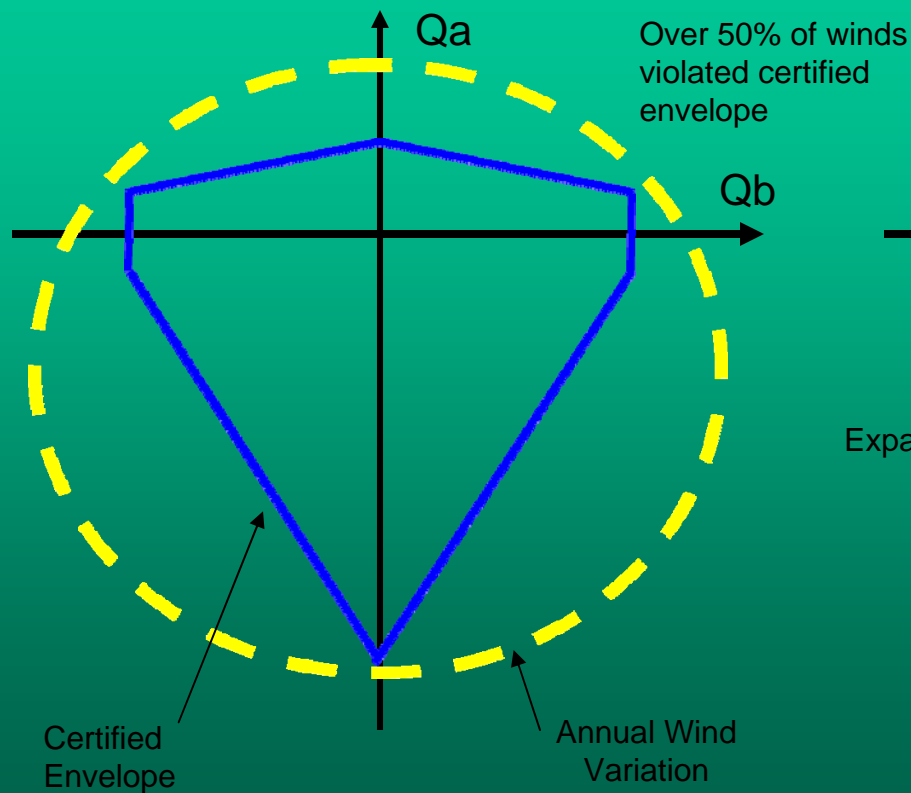
- Commit to a DOLILU approach during early development
  - Significantly improves margins
- Use additional margins on not well understood environments
- Will enhance robustness and simplify operations

# Ascent Design Operations Evolution

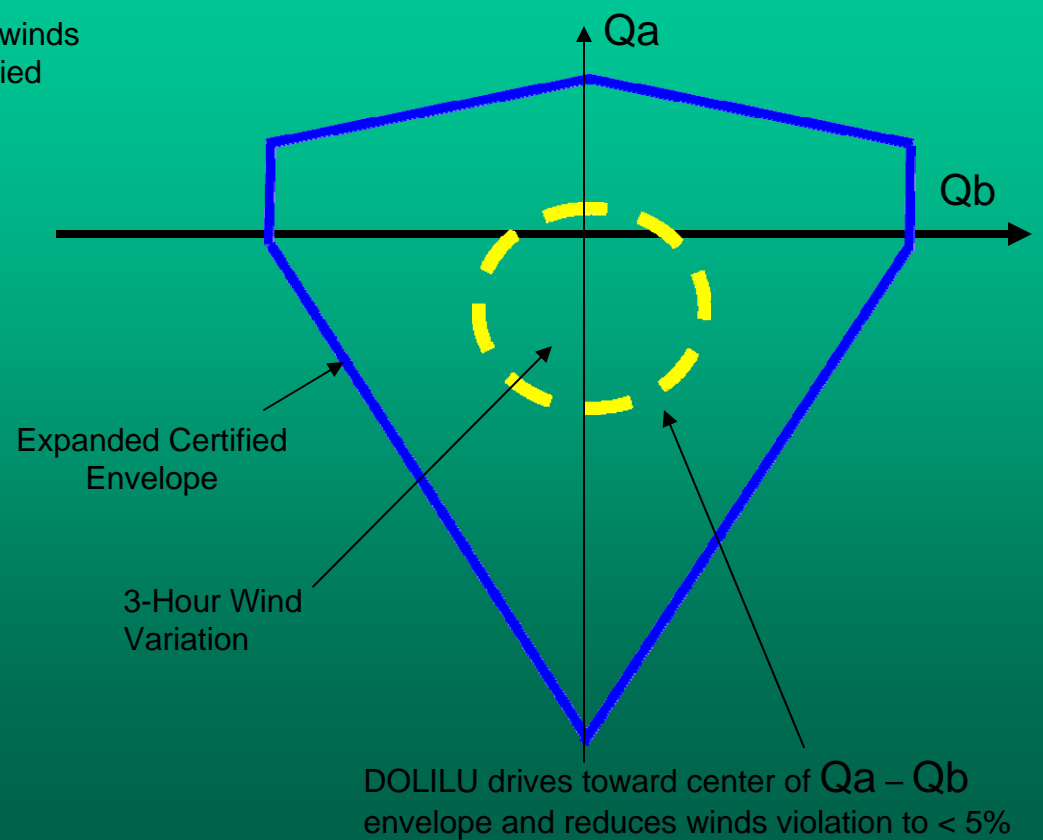


# Day-of-Launch I-Loads Evolution (10 years +)

## Early Flights Single I-Loads



## Present Flights DOLILU



# Where did We go Wrong?

## Problem

- **Insufficient definition of operational requirements during development phase**
  - Concentration on performance requirements but not on operational considerations
  - Shuttle design organizations were not responsible for operational cost
  - Very few incentives for development contractors

## Result

- **Very labor intensive (high operational cost) vehicle was developed and put into operations**

## Lesson

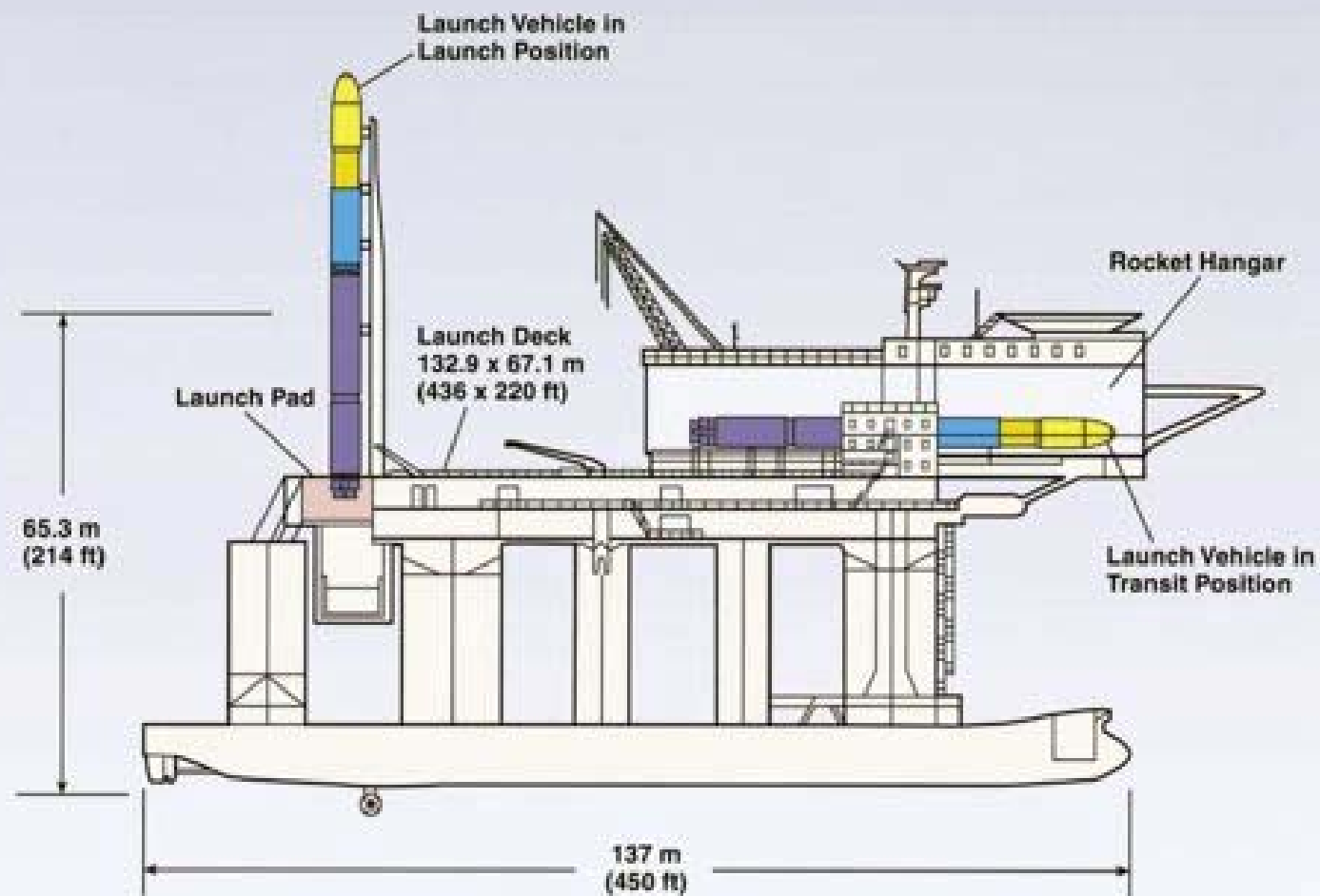
- **Must have the Concept of Operations defined**
- **Define and levy the operational requirements on contractors to support the Concept of Operations**
- **Must have continuity and integration between designers, ground operations, and flight operations requirements during the developmental phase**

# Sea Launch Zenit Rocket Very Efficient and Easy to Operate

Courtesy of the Sea Launch Company



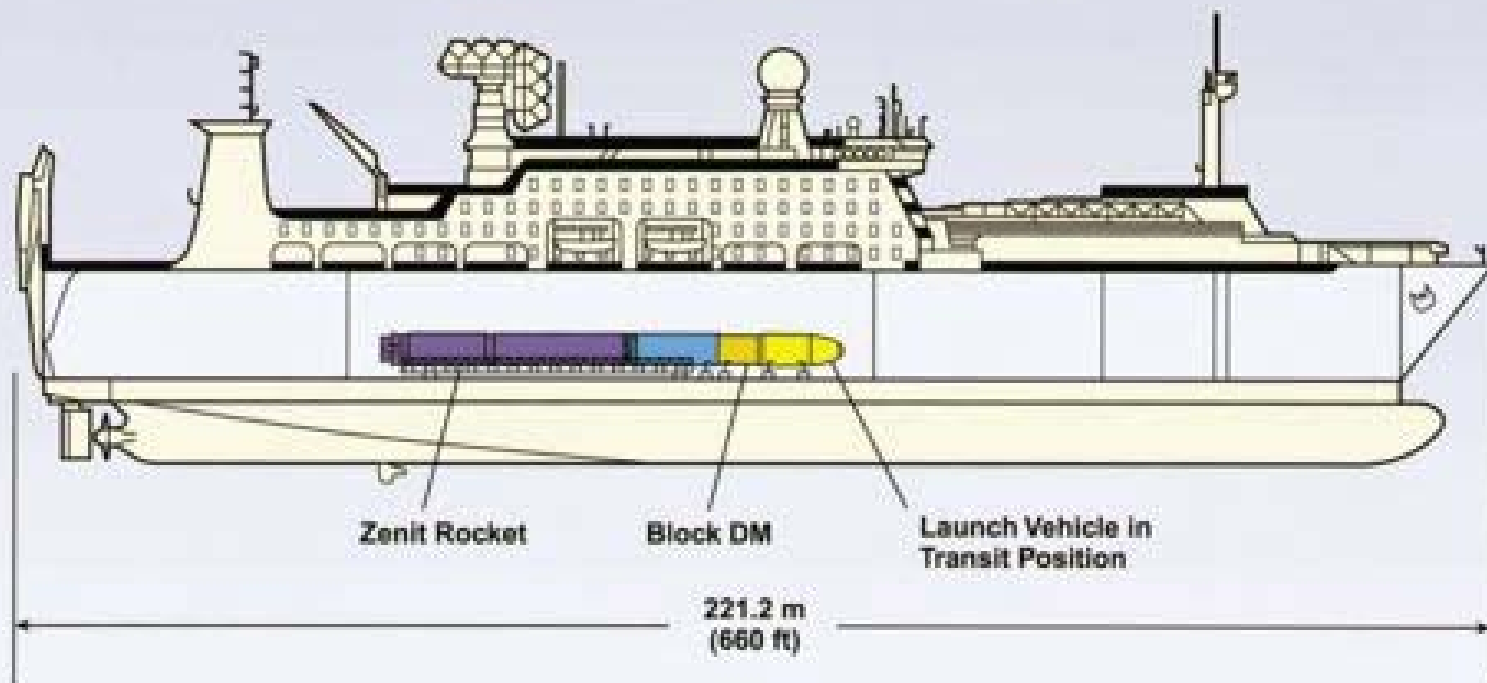
# Launch Platform



**Launch Platform**

Courtesy of the Sea Launch Company 11

# Assembly and Command Ship



Courtesy of the Sea Launch Company

12

# Launch



# Sea Launch – Zenit Derived Launch System



Courtesy of the Sea Launch Company

- Major integration of existing and new elements
  - Two stage Ukrainian Zenit
  - 3rd stage Russian Block DM
  - New payload accommodation & composite fairing
  - Modified semi-submersible oil drilling platform into a launch pad
  - New command and control and rocket assembly ship
- System was built and brought to operational state in less than 3.5 years
  - 24 flights to date

# Sea Launch Operations



Courtesy of the Sea Launch Company

- Integration of rocket stages and payload at home port in Long Beach, CA
- Launches performed from the Equator, 154 degrees west (south of Hawaii)

**Small Team performs ground checkout and launch**

	Ground Processing Team	Launch Team*
Americans	80	40
Russians	200	140
Ukrainians	50	50
Norwegians	75	70
Totals	405	300

\* Launch Team is a subset of the Ground Processing Team; Ground Processing team members that are not required to participate in launch at sea are sent back to their companies and are off the Sea Launch payroll

# Lessons Learned from Sea Launch

- **Zenit extremely automated launch vehicle**
  - Very little interaction with crew during checkout, pre-launch, and flight
- **Single string accountability, no duplications of effort (to some extent driven by export compliance restrictions)**
- **Low operational cost benefited from original design criteria of Zenit**
  - Rollout to pad, fuel and launch in 90 minutes
  - Allows very little time for ground or flight crew involvement
  - Imposes requirements for automatic processes

# The Big Lesson

- **If we want simple and cost effective operations we must design for operations**
  - Shuttle designed for performance and minimum development cost
  - Sea Launch Zenit Rocket designed to strict operational requirements
- **NASA is in control of operations destiny of new programs**
  - Narrow window of opportunity